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# DENSITY VARIATIONS IN THE EXOSPHERE FROM JUNE 1968 TO DECEMBER 1970

by

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## SUMMARY

Two satellites, Calsphere (1964-63C) and Dodecapole (1965-16G), have been used to determine weekly mean values of atmospheric density at heights near 1070 and 900 km respectively, between June 1968 and December 1970. Both satellites have nearly circular orbits and are therefore ideal for studying long-term variations in the atmosphere.

After correcting the values of density to both a fixed height and a fixed level of solar activity, it is possible to trace for the first time the progress of the semi-annual variation in the exosphere over 2½ years of high solar activity. The semi-annual variation in density is large, with the average value for the ratio of the October maxima to the July minima being about 2. When the results are combined with earlier data from Echo 2 there is evidence of a strong oscillation in the amplitude with a periodicity of 3 years.

Departmental Reference: Space 370

CONTENTS

## 1 INTRODUCTION

The author has studied[1-4] variations in exospheric density from April 1964 to December 1968, i.e. from just before the last solar minimum to near the maximum of the current sunspot cycle, using the orbit of Echo 2 (1964-04A). After the end of 1968, the perigee height of Echo 2 decreased rapidly and the satellite finally decayed on 7 June 1969. The most important outcome of these studies was the discovery of a pronounced semi-annual variation in exospheric density; the magnitude of this effect showed no definite dependence on the level of solar activity, but appeared to exhibit irregular year-to-year variations similar to those at lower heights[5]. The semi-annual variation in the exosphere was found to exceed the magnitude expected in the atmospheric models then current at dates before July 1966 and after April 1968, but was of the expected magnitude between those dates.

Since the large exospheric variations looked somewhat anomalous during certain years, it was decided to extend the study over a 2½ year period of high solar activity using Calsphere (1964-63C) and Dodecapole (1965-16G). These two satellites are in near-circular orbits, which are ideal for investigations of the semi-annual effect. In fact, the author has previously used data from Calsphere[6] during 1965 to check on the magnitude of the electric drag experienced by Echo 2. This latter effect was found to be small, while the large semi-annual variation was confirmed. Both Calsphere 1 and Dodecapole 1 have been used by Brescia[7] to determine atmospheric density for the years 1966-8. The 'five-card elements' of Spadats/Spacetrack are normally issued too infrequently to be really useful for exospheric density studies using these two satellites; the present study was made possible by the US Naval Research Laboratory, which kindly supplied the orbital data.

## 2 ORBITAL DATA AND METHOD OF ANALYSIS

Calsphere 1 (1964-63C) is a polished aluminium sphere with a diameter of 0.36 m. Dodecapole 1 (1965-16G) consists of a sphere with twelve hollow rods protruding from the surface[7]; the central sphere has a diameter of 0.26 m, while the rods, which are symmetrically distributed, have a diameter of 0.0127 m and a length of 7.62 m. The cross-sectional areas $A$ and masses $m$ of the two satellites are given in Table 1.

Table 1

Satellites used

| Satellite | $A$ $m^2$ | $m$ kg | $A/m$ $m^2kg^{-1}$ | $\delta$ $m^2kg^{-1}$ | $i$ deg | $\bar{y}_0$ km |
|---|---|---|---|---|---|---|
| Calsphere | 0.0993 | 0.98 | 0.1013 | 0.2634 | 89.9 | 1070 |
| Dodecapole | 0.929 | 3.736 | 0.2487 | 0.6084 | 70.1 | 900 |

Orbital data for the two satellites have been supplied at weekly intervals by NRL. The data consist of the semi major axis $a$, eccentricity $e$, inclination $i$, right ascension $\Omega$, argument of perigee $\omega$, mean anomaly $M$ and orbital period $T$.

Since the eccentricities of both orbits are very small, mean values of air density can be found at the mean height assuming a circular orbit. The eccentricities are also sufficiently small for the effects of solar radiation pressure on the orbital period to be negligible. The rate of change of orbital period $\dot{T}$ is found directly from the period by differencing for the NRL data.

The average air density $\rho$ experienced by a satellite in a circular orbit of radius $a$ is related to the rate of change of period by[8]

$$\rho = -\dot{T}/(3\pi a\delta) \quad , \tag{1}$$

where $\delta = FAC_D/m$, $C_D$ is the drag coefficient and $F$ is a factor which allows for atmospheric rotation. The molecular speed ratio is in the region 3.5 to 4.2, while the molecular weight of the atmosphere is in the range 4.5 to 5.5. As a result, we assume[9] that $C_D$ has a value of 2.6 for both satellites. Equation (1) gives the density at the mean height $\bar{y}$ represented by

$$\bar{y} = a - R(1 - \tfrac{1}{2}\,\varepsilon \sin^2 i) \quad , \tag{2}$$

where $R = 6378.2$ km and $\varepsilon(= 0.00335)$ is the ellipticity of the earth. Errors introduced by using equation (1) are discussed in section 3.

For each satellite the values of density were adjusted to a fixed height $\bar{y}_0$, which is the average value of the mean height over the time interval considered. The adjustment was made using a model atmosphere[5] based on

Jacchia's 1965 static diffusion profiles[10]. Since we have nearly circular orbits, a mean value can be used for the exospheric temperature. This mean value $T_m(K)$ is given by

$$T_m = 1.14(418 + 3.60S_m) \quad ,$$

where $S_m$ is the solar 10.7 cm flux (in units of $10^{-22}$ W m$^{-2}$ Hz$^{-1}$) averaged over the 55 days prior to the date of the density determination. Variations of the exospheric temperature, $T_\infty$, within one solar rotation were incorporated using

$$T_\infty = T_m + 1.8(S - S_m) \quad .$$

The 'current' level of solar activity $S$ was taken as the mean of the values of solar flux over seven days centred on the day before the date of the density determination.

## 3 RESULTS

The results are presented in Tables 3 and 4, which give values for the rate of change of orbital period $\dot{T}$, the mean height and the mean density at that height. The last two columns give $\rho_0$, the density adjusted to a fixed height $\bar{y}_0$, and $\rho_{STD}$, the density adjusted to both a fixed height $\bar{y}_0$ and a fixed 10.7 cm flux of $150 \times 10^{-22}$ W m$^{-2}$ Hz$^{-1}$. The values of $\bar{y}_0$ used for the two satellites are shown in Table 1. Little error is introduced in adjusting to a fixed height since, over the time interval considered, the mean height had only decreased by 3.5 km for 1964-63C and 25.3 km for 1965-16G.

Fig.1 shows the weekly values of density $\rho_0$ at 1070 km from Calsphere and 900 km from Dodecapole, together with the daily values of the 10.7 cm solar radiation flux. Even with the averaging effect produced by using orbital data at weekly intervals, there is still strong evidence of density variations associated with the 27-day solar rotation period. The values of density are too infrequent to allow any attempt at correlation with solar activity, however.

Fig.2 shows values of density adjusted to both a fixed height and a fixed 10.7 cm flux of $150 \times 10^{-22}$ W m$^{-2}$ Hz$^{-1}$. The response of the density to variations in solar activity has been greatly reduced. Values of the daily geomagnetic planetary amplitude $A_p$ are also shown in Fig.2 and it is evident that several of the remaining peaks in density are associated with large magnetic storms.

The densities in Fig.2 exhibit a pronounced semi-annual variation and to give a clearer picture of this variation the results have been smoothed by omitting the high values associated with magnetic storms and by taking running means of two. These smoothed values are shown in Fig.3. The dates of the extreme values are given in Table 2; it should be remembered that the time resolution allowed by the data is not very good, since the original data were only at intervals of 7 days. As can be seen from Table 2, the dates of the extrema given by the two satellites are in general consistent with each other and also with the dates for the lower thermosphere obtained by King-Hele and Walker from analysis[11,12] of the orbits of 1967-31A and 1969-108A. The most obvious inconsistency is the date of the 1970 secondary maximum, which cannot really be defined by the exospheric data presented here owing to the three large magnetic storms in March and April. The March maximum in 1969 was also shown by 1967-31A at 185 km.

The extreme values of density at both 900 km and 1070 km are given in Table 2. These extreme values were obtained by averaging the two highest or lowest densities. Since the densities are already running means of two and the original data represented an average over 7 days, the values quoted are essentially an average over 21 days. Also given in Table 2 is the magnitude of the semi-annual variation represented by the ratio of successive maxima and minima. These ratios are shown in Fig.4 together with data for earlier years obtained[4] from Echo 2. The height at which the Echo 2 data applies decreased from about 1130 km in 1964 to about 960 km in late 1968.

Fig.4 suggests that the amplitude of the semi-annual effect undergoes a strong oscillation, the density ratio in the exosphere ranging between a minimum of 1.25 and a maximum of about 2.5 once every 3 years. This is not the first evidence for such a periodicity; King-Hele and Walker have previously suggested[13] that the amplitude of the semi-annual variation oscillates with a period of about 33 months. In Fig.5 we plot the density ratio at a height of 500 km obtained from the densities derived in Ref.13 using the semi-annual temperature changes determined by Jacchia, Slowey and Campbell[14] for dates between 1958 and April 1966. For dates between April 1966 and November 1967 the values are averages for four satellites[15] (1963-27A, 1964-11A, 1965-53A and 1965-55A) in the 500 km height region. For 1968 the results are from three satellites[13,16] (1963-27A, 1965-53A and 1966-118A). Since the amplitude at heights near 1000 km is similar to the amplitude near 500 km, we have included the average of the values from 1964-63C and 1965-16G for dates from November 1968 to 1970.

Table 2

Semi-annual variation in the exosphere and lower thermosphere

| Event | | Satellite | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1964-63C | | | 1965-16G | | | 1967-31A | | | 1969-108A | | |
| | | Date | $\rho_{1070}$ pgm$^{-3}$ | Max/min ratio | Date | $\rho_{900}$ pgm$^{-3}$ | Max/min ratio | Date | $\rho_{165}$ pgm$^{-3}$ | Max/min ratio | Date | $\rho_{164}$ pgm$^{-3}$ | Max/min ratio |
| 1968 | primary minimum | Jul 14 | 1.98 | | Aug 4 | 6.47 | | Jul 26 | 0.38 | | | | |
| | primary maximum | Nov 10 | 4.16 | 2.10 | Oct 20 | 14.21 | 2.20 | Oct 31 | 0.50 | 1.32 | | | |
| 1969 | secondary minimum | Jan 12 | 2.60 | 1.60 | Jan 12 | 7.32 | 1.94 | Jan 28 | 0.41 | 1.22 | | | |
| | secondary maximum | Mar 16 | 3.53 | 1.36 | Mar 26 | 11.49 | 1.58 | Mar 19 | 0.50 | 1.22 | | | |
| | primary minimum | July 27 | 1.90 | 1.87 | Jul 27 | 6.39 | 2.05 | Aug 3 | 0.35 | 1.43 | | | |
| | primary maximum | Nov 2 | 3.72 | 1.97 | Nov 9 | 11.24 | 1.99 | | | | | | |
| 1970 | secondary minimum | Jan 11 | 2.75 | 1.35 | Feb 15 | 6.85 | 1.65 | | | | Jan 13 | 0.95 | |
| | secondary maximum | May 3 | 3.42 | 1.24 | Mar 22 | 10.5 | 1.53 | | | | Apr 10 | 1.23 | 1.29 |
| | primary minimum | Aug 9 | 2.02 | 1.69 | Aug 9 | 5.60 | 1.89 | | | | Aug 10 | 0.93 | 1.32 |
| | primary maximum | Oct 19 | 4.41 | 2.18 | Oct 19 | 15.6 | 2.83 | | | | | | |

Fig.5 shows clearly that a 3-year periodicity has existed in the amplitude of the semi-annual variation from 1958 to 1970, i.e. over all 13 years for which satellite data are available.

In the past, attempts have been made[10] to represent the semi-annual variation in density by assuming temperature variations in the thermosphere, the magnitude of the temperature variation being proportional to the 10.7 cm solar radiation flux. As soon as the first study[1] was performed using Echo 2, however, it was evident that the amplitude in the exosphere was far too large to be represented entirely by such temperature variations. The inadequacy of this representation was confirmed as soon as results became available[11,17] from the orbits of satellites with perigee heights in the region between 150 and 200 km. A study of rocket results showed that the effect is also present at 90 km, a near-isopycnic level for other variations.

Jacchia has recently reconsidered[18] the semi-annual effect and suggested that it can be represented by a pure density variation whose amplitude is a function of height. Using data from seven satellites averaged over a number of years and the rocket data of Ref.5, he has found that the semi-annual variation in density can be represented by the empirical relation

$$\Delta \log_{10} \rho = f(z)g(t) \quad ,$$

where $f(z) = (5.876 \times 10^{-7} z^{2.331} + 0.06328) \quad \exp(-2.868 \times 10^{-3} z)$

$$f(t) = 0.02835 + 0.3817[1 + 0.4671 \sin (2\pi\tau + 4.137)] \sin (4\pi\tau + 4.259)$$

with

$$\tau = \Phi + 0.09544 \{[\tfrac{1}{2} + \tfrac{1}{2} \sin (2\pi\Phi + 6.035)]^{1.650} - \tfrac{1}{2}\} \quad .$$

The height $z$ is measured in km and $\Phi$ is the phase given by

$$\Phi = (t - 36204)/365.2422 \quad ,$$

$t$ being the time in MJD.

The density ratio between the October maximum and the July minimum as given by the above relation is shown in Fig.6. Also shown are the average values over 3 years (a suitable time scale in view of the periodicity discussed above) for the same ratio obtained from the two satellites studied in this paper.

It appears that Jacchia's empirical relation gives a good representation for the average value of the semi-annual amplitude in the exosphere. The near-agreement at 900 km is particularly satisfactory since there was a large gap in Jacchia's data between 595 and 1130 km.

The main errors introduced by using equation (2) to evaluate mean density are due to neglect of the diurnal bulge and the seasonal-latitudinal variation of helium. If the diurnal density variation with angular distance from the centre of the bulge was exactly sinusoidal, there would be no error from this source. Since a sinusoidal variation should be a reasonable approximation at heights near 1000 km, the error from this source should be no more than a few per cent.

The effect of the seasonal variation of helium as given in Jacchia's latest model atmosphere[19] has been examined in some detail. If an allowance was made for it and mean densities at the equator were obtained, the values would be unchanged at the equinoxes, but reduced by about 20% at the solstices. Inclusion of the effect in the data analysis of this Report would not affect the conclusions about the existence of the 3-year periodicity, although the magnitude of the semi-annual effect would be increased by about 10% on average. At present there are no direct measurements of seasonal variations in the 1000 km height region, while the model is mainly based on results from a single satellite, Explorer 19, at heights near 700 km.

## 4 CONCLUSIONS

The present study of variations in air density at heights of 900 and 1070 km from June 1968 to December 1970 using Dodecapole and Calsphere has provided a useful extension of the earlier exospheric studies made by analysis of the orbit of Echo 2. There are two main conclusions:

(1) The year-to-year variations in the amplitude of the semi-annual variation may not be so irregular as we have sometimes believed[5,18]. Results over 7 years at heights between 900 and 1130 km indicate that the amplitude in the exosphere undergoes a strong oscillation, the density ratio between successive maxima and minima varying between 1.25 and 2.5 once every 3 years. The same periodicity is also present at heights near 500 km. The amplitude of the semi-annual variation appears to be unrelated to the level of solar activity.

(2) The variation of the average amplitude with height in the exosphere is well represented by the empirical relation recently given[18] by Jacchia.

Acknowledgement

The author would like to thank the US Naval Research Laboratory for kindly supplying the orbital data used in this paper.

# Table.3

Table.3. Values of acceleration and density for 1964—63C

| DATE | TDOT | VBAR | RHO | RHOO | RHOSTD |
|---|---|---|---|---|---|
| 40019,5 | -5,456E-08 | 1072,3 | 2.954E-15 | 2.981E-15 | 3,372E-15 |
| 40026,5 | -4,266E-08 | 1072,3 | 2.310E-15 | 2.331E-15 | 2,594E-15 |
| 40033,5 | -3,373E-08 | 1072,3 | 1.826E-15 | 1.843E-15 | 1,918E-15 |
| 40040,5 | -3.770E-08 | 1072.2 | 2.041E-15 | 2.059E-15 | 2,547E-15 |
| 40047,5 | -2,480E-08 | 1072,2 | 1.343E-15 | 1.355E-15 | 1,454E-15 |
| 40054,5 | -4,067E-08 | 1072,2 | 2.202E-15 | 2,222E-15 | 2,478E-15 |
| 40061,5 | -3,373E-08 | 1072.2 | 1.826E-15 | 1,842E-15 | 2,113E-15 |
| 40068,5 | -3,770E-08 | 1072.2 | 2.041E-15 | 2.059E-15 | 2.441E-15 |
| 40075,5 | -2,976E-08 | 1072,2 | 1.611E-15 | 1.625E-15 | 1,922E-15 |
| 40082,5 | -4,762E-08 | 1072,1 | 2.578E-15 | 2.601E-15 | 2,573E-15 |
| 40089,5 | -4,266E-08 | 1072,1 | 2.310E-15 | 2,330E-15 | 2,416E-15 |
| 40096,5 | -3.770E-08 | 1072.1 | 2.041E-15 | 2.058E-15 | 2,617E-15 |
| 40103,5 | -4,365E-08 | 1072.1 | 2.364E-15 | 2.383E-15 | 2,822E-15 |
| 40110,5 | -5,853E-08 | 1072,1 | 3.169E-15 | 3.195E-15 | 3,450E-15 |
| 40117,5 | -4,663E-08 | 1072,0 | 2.525E-15 | 2,545E-15 | 3,051E-15 |
| 40124,5 | -4,861E-08 | 1072.0 | 2.632E-15 | 2.653E-15 | 2.977E-15 |
| 40131,5 | -5,754E-08 | 1072,0 | 3.116E-15 | 3,140E-15 | 3,421E-15 |
| 40138,5 | -5,357E-08 | 1072,0 | 2.901E-15 | 2,923E-15 | 3.318E-15 |
| 40145,5 | -6,548E-08 | 1071.9 | 3.545E-15 | 3,572E-15 | 4,233E-15 |
| 40152,5 | -6,745E-08 | 1071.9 | 3.653E-15 | 3.681E-15 | 3,557E-15 |
| 40159,5 | -1.032E-07 | 1071.9 | 5.587E-15 | 5,631E-15 | 5,033E-15 |
| 40166,5 | -7,837E-08 | 1071.8 | 4.244E-15 | 4,275E-15 | 4.620E-15 |
| 40173,5 | -6.349E-08 | 1071.8 | 3.438E-15 | 3.462E-15 | 3,850E-15 |
| 40180,5 | -6,647E-08 | 1071.8 | 3.599E-15 | 3.624E-15 | 3,898E-15 |
| 40187,5 | -6,647E-08 | 1071.7 | 3.599E-15 | 3,624E-15 | 4.042E-15 |
| 40194,5 | -6,349E-08 | 1071.7 | 3.438E-15 | 3.462E-15 | 3,397E-15 |
| 40201,5 | -5,060E-08 | 1071.7 | 2.740E-15 | 2,758E-15 | 2,867E-15 |
| 40208,5 | -5,456E-08 | 1071.6 | 2.955E-15 | 2.974E-15 | 3,292E-15 |
| 40215,5 | -6,448E-08 | 1071.6 | 3.492E-15 | 3.515E-15 | 3.558E-15 |

Table.3 (cont'd)

| DATE | TDOT | VBAR | RHO | RHOO | RHOSTD |
|---|---|---|---|---|---|
| 40229.5 | -6.052E-08 | 1071.6 | 3.277E-15 | 3.299E-15 | 2.808E-15 |
| 40236.5 | -4.742E-08 | 1071.5 | 2.579E-15 | 2.595E-15 | 2.379E-15 |
| 40243.5 | -4.861E-08 | 1071.5 | 2.632E-15 | 2.648E-15 | 2.820E-15 |
| 40250.5 | -4.663E-08 | 1071.5 | 2.525E-15 | 2.540E-15 | 2.749E-15 |
| 40257.5 | -6.548E-08 | 1071.5 | 3.546E-15 | 3.566E-15 | 3.752E-15 |
| 40264.5 | -4.861E-08 | 1071.4 | 2.632E-15 | 2.647E-15 | 2.952E-15 |
| 40271.5 | -5.655E-08 | 1071.4 | 3.062E-15 | 3.080E-15 | 3.201E-15 |
| 40278.5 | -8.433E-08 | 1071.4 | 4.566E-15 | 4.595E-15 | 3.305E-15 |
| 40285.5 | -6.448E-08 | 1071.3 | 3.492E-15 | 3.511E-15 | 3.509E-15 |
| 40292.5 | -5.853E-08 | 1071.3 | 3.170E-15 | 3.186E-15 | 3.446E-15 |
| 40299.5 | -9.623E-08 | 1071.3 | 5.211E-15 | 5.242E-15 | 3.720E-15 |
| 40306.5 | -1.121E-07 | 1071.2 | 6.071E-15 | 6.105E-15 | 4.233E-15 |
| 40313.5 | -7.242E-08 | 1071.2 | 3.922E-15 | .943E-15 | 2.753E-15 |
| 40320.5 | -6.746E-08 | 1071.1 | 3.653E-15 | 3.671E-15 | 3.024E-15 |
| 40327.5 | -8.433E-08 | 1071.1 | 4.566E-15 | 4.589E-15 | 3.473E-15 |
| 40334.5 | -6.151E-08 | 1071.1 | 3.331E-15 | 3.346E-15 | 2.969E-15 |
| 40341.5 | -6.448E-08 | 1071.0 | 3.492E-15 | 3.507E-15 | 3.508E-15 |
| 40348.5 | -5.159E-08 | 1071.0 | 2.794E-15 | 2.805E-15 | 2.739E-15 |
| 40355.5 | -7.837E-08 | 1071.0 | 4.244E-15 | 4.262E-15 | 3.953E-15 |
| 40362.5 | -6.250E-08 | 1071.0 | 3.385E-15 | 3.398E-15 | 3.069E-15 |
| 40370.0 | -5.122E-08 | 1070.9 | 2.774E-15 | 2.784E-15 | 3.046E-15 |
| 40377.0 | -4.167E-08 | 1070.9 | 2.256E-15 | 2.265E-15 | 2.255E-15 |
| 40383.5 | -7.540E-08 | 1070.9 | 4.083E-15 | 4.101E-15 | 2.465E-15 |
| 40390.5 | -6.052E-08 | 1070.8 | 3.277E-15 | 3.289E-15 | 2.803E-15 |
| 40397.5 | -3.968E-08 | 1070.8 | 2.149E-15 | 2.156E-15 | 2.608E-15 |
| 40404.5 | -3.274E-08 | 1070.8 | 1.773E-15 | 1.77[illegible]E-15 | 1.776E-15 |
| 40411.5 | -4.861E-08 | 1070.8 | 2.633E-15 | 2.641E-15 | 2.341E-15 |
| 40418.5 | -4.067E-08 | 1070.8 | 2.203E-15 | 2.210E-15 | 2.414E-15 |
| 40425.5 | -2.480E-08 | 1070.8 | 1.343E-15 | 1.347E-15 | 1.683E-15 |
| 40432.5 | -3.075E-08 | 1070.7 | 1.666E-15 | 1.670E-15 | 1.778E-15 |

Table.3 (cont'd)

Table.3 (cont'd)

| DATE | TDOT | VBAR | RHO | RHOO | RHOSTD |
|---|---|---|---|---|---|
| 40439.5 | -5.159E-08 | 1070.7 | 2.794E-15 | 2.802E-15 | 2.[illegible]50E-15 |
| 40446.5 | -4.365E-08 | 1070.7 | 2.364E-15 | 2.370E-15 | 2.996E-15 |
| 40453.5 | -2.679E-08 | 1070.7 | 1.451E-15 | 1.454E-15 | 2.093E-15 |
| 40460.5 | -4.167E-08 | 1070.7 | 2.257E-15 | 2.263E-15 | 2.429E-15 |
| 40467.5 | -5.952E-08 | 1070.6 | 3.224E-15 | 3.232E-15 | 3.525E-15 |
| 40474.5 | -4.167E-08 | 1070.6 | 2.257E-15 | 2.262E-15 | 2.999E-15 |
| 40481.5 | -3.869E-08 | 1070.6 | 2.095E-15 | 2.100E-15 | 2.380E-15 |
| 40488.5 | -5.258E-08 | 1070.6 | 2.848E-15 | 2.854E-15 | 3.127E-15 |
| 40495.5 | -6.250E-08 | 1070.6 | 3.385E-15 | 3.392E-15 | 4.045E-15 |
| 40502.5 | -4.663E-08 | 1070.5 | 2.525E-15 | 2.530E-15 | 2.953E-15 |
| 40509.5 | -4.563E-08 | 1070.5 | 2.471E-15 | 2.476E-15 | 3.170E-15 |
| 40516.5 | -7.143E-08 | 1070.5 | 3.868E-15 | 3.876E-15 | 3.656E-15 |
| 40523.5 | -8.333E-08 | 1070.4 | 4.513E-15 | 4.522E-15 | 3.769E-15 |
| 40531.0 | -6.076E-08 | 1070.4 | 3.291E-15 | 3.296E-15 | 3.698E-15 |
| 40538.0 | -5.903E-08 | 1070.4 | 3.197E-15 | 3.202E-15 | 3.686E-15 |
| 40544.5 | -6.548E-08 | 1070.3 | 3.546E-15 | 3.551E-15 | 3.089E-15 |
| 40551.5 | -7.937E-08 | 1070.3 | 4.298E-15 | 4.304E-15 | 3.182E-15 |
| 40558.5 | -6.746E-08 | 1070.3 | 3.654E-15 | 3.658E-15 | 3.720E-15 |
| 40565.5 | -5.069E-08 | 1070.3 | 2.740E-15 | 2.743E-15 | 3.086E-15 |
| 40573.0 | -5.816E-08 | 1070.2 | 3.150E-15 | 3.153E-15 | 3.150E-15 |
| 40580.0 | -6.019E-08 | 1070.2 | 3.260E-15 | 3.262E-15 | 3.084E-15 |
| 40586.5 | -5.754E-08 | 1070.2 | 3.116E-15 | 3.119E-15 | 2.973E-15 |
| 40593.5 | -4.266E-08 | 1070.1 | 2.310E-15 | 2.312E-15 | 2.609E-15 |
| 40600.5 | -6.250E-08 | 1070.1 | 3.385E-15 | 3.387E-15 | 2.932E-15 |
| 40607.5 | -6.845E-08 | 1070.1 | 3.707E-15 | 3.709E-15 | 3.179E-15 |
| 40614.5 | -5.357E-08 | 1070.1 | 2.901E-15 | 2.902E-15 | 2.682E-15 |
| 40622.0 | -4.774E-08 | 1070.0 | 2.586E-15 | 2.586E-15 | 2.783E-15 |
| 40629.0 | -6.597E-08 | 1070.0 | 3.573E-15 | 3.573E-15 | 2.742E-15 |
| 40635.5 | -7.639E-08 | 1070.0 | 4.137E-15 | 4.137E-15 | 2.748E-15 |
| 40642.5 | -7.242E-08 | 1069.9 | 3.922E-15 | 3.921E-15 | 2.762E-15 |

Table.3 (cont'd)

Table.3 (cont'd)

| DATE | TDOT | VBAR | RHO | RHOO | RHOSTD |
|---|---|---|---|---|---|
| 40649,5 | -7.242E-08 | 1069.9 | 3.922E-15 | 3.921E-15 | 2,863E-15 |
| 40656,5 | -9.127E-08 | 1069.9 | 4.943E-15 | 4.941E-15 | 3,794E-15 |
| 40663,5 | -5.655E-08 | 1069.8 | 3.063E-15 | 3.061E-15 | 2,830E-15 |
| 40670,5 | -6.349E-08 | 1069.8 | 3.439E-15 | 3.436E-15 | 2.790E-15 |
| 40677,5 | -8.929E-08 | 1069.8 | 4.836E-15 | 4.831E-15 | 3,968E-15 |
| 40684,5 | -8.532E-08 | 1069.7 | 4.621E-15 | 4.615E-15 | 2,903E-15 |
| 40691,3 | -8.036E-08 | 1069.7 | 4.352E-15 | 4.346E-15 | 3,180E-15 |
| 40698,5 | -7.738E-08 | 1069.7 | 4.191E-15 | 4.185E-15 | 4,225E-15 |
| 40705,5 | -6.448E-08 | 1069.6 | 3.493E-15 | 3.487E-15 | 3,359E-15 |
| 40712,5 | -7.837E-08 | 1069.6 | 4.245E-15 | 4.238E-15 | 3,752E-15 |
| 40719,5 | -6.746E-08 | 1069.6 | 3.654E-15 | 3.647E-15 | 2,816E-15 |
| 40726,5 | -7.837E-08 | 1069.5 | 4.245E-15 | 4.236E-15 | 3.026E-15 |
| 40733,5 | -8.135E-08 | 1069.5 | 4.406E-15 | 4.396E-15 | 3.754E-15 |
| 40740,5 | -6.647E-08 | 1069.4 | 3.600E-15 | 3.592E-15 | 3.493E-15 |
| 40747,5 | -4.762E-08 | 1069.4 | 2.579E-15 | 2.573E-15 | 2,622E-15 |
| 40754,5 | -7.540E-08 | 1069.4 | 4.084E-15 | 4.073E-15 | 2,952E-15 |
| 40761,5 | -5.853E-08 | 1069.4 | 3.170E-15 | 3.162E-15 | 2,928E-15 |
| 40768,0 | -6.250E-08 | 1069.3 | 3.385E-15 | 3.376E-15 | 2,722E-15 |
| 40774,5 | -5.952E-08 | 1069.3 | 3.224E-15 | 3.214E-15 | 2,529E-15 |
| 40781,5 | -3.968E-08 | 1069.3 | 2.149E-15 | 2.143E-15 | 2,348E-15 |
| 40789,0 | -3.906E-08 | 1069.3 | 2.116E-15 | 2.110E-15 | 2,147E-15 |
| 40796,5 | -5.456E-08 | 1069.2 | 2.956E-15 | 2.946E-15 | 2,624E-15 |
| 40803,5 | -3.373E-08 | 1069.2 | 1.827E-15 | 1.821E-15 | 2,045E-15 |
| 40810,5 | -3.075E-08 | 1069.2 | 1.666E-15 | 1.661E-15 | 1,836E-15 |
| 40817,5 | -4.563E-08 | 1069.2 | 2.472E-15 | 2.464E-15 | 2,532E-15 |
| 40824,5 | -4.464E-08 | 1069.2 | 2.418E-15 | 2.410E-15 | 2,734E-15 |
| 40832,0 | -5.035E-08 | 1069.1 | 2.727E-15 | 2.718E-15 | 2,826E-15 |
| 40839,0 | -4.861E-08 | 1069.1 | 2.633E-15 | 2.624E-15 | 2,772E-15 |
| 40846,0 | -4.774E-08 | 1069.1 | 2.586E-15 | 2.577E-15 | 3,283E-15 |
| 40853,0 | -5.671E-08 | 1069.1 | 3.072E-15 | 3.061E-15 | 3,238E-15 |

Table.3 (concl'd)

| DATE | TDOT | VBAR | RHO | RHOO | RHOSTD |
|---|---|---|---|---|---|
| 40859.5 | -6.548E-08 | 1069.0 | 3.547E-15 | 3.533E-15 | 4.004E-15 |
| 40867.0 | -4.774E-08 | 1069.0 | 2.586E-15 | 2.576E-15 | 2.947E-15 |
| 40874.5 | -7.242E-08 | 1069.0 | 3.923E-15 | 3.907E-15 | 4.562E-15 |
| 40881.5 | -7.242E-08 | 1069.0 | 3.923E-15 | 3.907E-15 | 4.566E-15 |
| 40888.5 | -9.425E-08 | 1068.9 | 5.105E-15 | 5.081E-15 | 4.328E-15 |
| 40895.0 | -9.491E-08 | 1068.9 | 5.141E-15 | 5.117E-15 | 5.130E-15 |
| 40901.5 | -8.730E-08 | 1068.8 | 4.729E-15 | 4.706E-15 | 4.541E-15 |
| 40908.5 | -8.631E-08 | 1068.8 | 4.675E-15 | 4.650E-15 | 3.461E-15 |
| 40915.5 | -8.433E-08 | 1068.8 | 4.568E-15 | 4.545E-15 | 4.672E-15 |

Table.4. Values of acceleration and density for 1965—16G

| DATE | TDOT | YBAR | RHO | RHOO | RHOSTD |
|---|---|---|---|---|---|
| 40019.5 | -3,502E-07 | 913.4 | 8.387E-15 | 9.130E-15 | 1.081E-14 |
| 40026.5 | -2,619E-07 | 913.2 | 6.272E-15 | 6.827E-15 | 7.910E-15 |
| 40033.5 | -2,609E-07 | 913.1 | 6.249E-15 | 6.815E-15 | 7.203E-15 |
| 40040.5 | -2,401E-07 | 913.0 | 5.750E-15 | 6.221E-15 | 8.300E-15 |
| 40047.5 | -2,093E-07 | 912.9 | 5.013E-15 | 5.453E-15 | 6.012E-15 |
| 40054.5 | -2,381E-07 | 912.8 | 5.703E-15 | 6.189E-15 | 7.193E-15 |
| 40061.5 | -2,192E-07 | 912.7 | 5.251E-15 | 5.688E-15 | 6.866E-15 |
| 40068.5 | -1,845E-07 | 912.6 | 4.420E-15 | 4.778E-15 | 6.030E-15 |
| 40075.5 | -2,063E-07 | 912.5 | 4.942E-15 | 5.341E-15 | 6.716E-15 |
| 40082.5 | -2,738E-07 | 912.4 | 6.558E-15 | 7.133E-15 | 7.025E-15 |
| 40089.5 | -2,431E-07 | 912.2 | 5.822E-15 | 6.315E-15 | 6.641E-15 |
| 40096.5 | -1,875E-07 | 912.1 | 4.491E-15 | 4.830E-15 | 6.681E-15 |
| 40103.5 | -2,589E-07 | 912.0 | 6.202E-15 | 6.684E-15 | 8.418E-15 |
| 40110.5 | -3,373E-07 | 911.9 | 8.080E-15 | 8.731E-15 | 9.704E-15 |
| 40117.5 | -2,808E-07 | 911.7 | 6.725E-15 | 7.231E-15 | 9.257E-15 |
| 40124.5 | -2,698E-07 | 911.6 | 6.464E-15 | 6.962E-15 | 8.155E-15 |
| 40131.5 | -4,405E-07 | 911.4 | 1.055E-14 | 1.137E-14 | 1.279E-14 |
| 40138.5 | -4,157E-07 | 911.2 | 9.958E-15 | 1.070E-14 | 1.273E-14 |
| 40145.5 | -4,623E-07 | 911.0 | 1.108E-14 | 1.186E-14 | 1.496E-14 |
| 40152.5 | -5,565E-07 | 910.8 | 1.333E-14 | 1.436E-14 | 1.369E-14 |
| 40159.5 | -8,204E-07 | 910.5 | 1.966E-14 | 2.118E-14 | 1.810E-14 |
| 40166.5 | -4,583E-07 | 910.2 | 1.098E-14 | 1.174E-14 | 1.307E-14 |
| 40173.5 | -3,740E-07 | 910.0 | 8.961E-15 | 9.555E-15 | 1.106E-14 |
| 40180.5 | -4,018E-07 | 909.8 | 9.627E-15 | 1.026E-14 | 1.135E-14 |
| 40187.5 | -3,770E-07 | 909.6 | 9.033E-15 | 9.609E-15 | 1.117E-14 |
| 40194.5 | -4,375E-07 | 909.4 | 1.048E-14 | 1.116E-14 | 1.177E-14 |
| 40201.5 | -3,740E-07 | 909.2 | 8.962E-15 | 9.530E-15 | 1.005E-14 |
| 40208.5 | -3,710E-07 | 909.0 | 8.891E-15 | 9.426E-15 | 1.084E-14 |
| 40215.5 | -4,722E-07 | 908.8 | 1.132E-14 | 1.201E-14 | 1.222E-14 |
| 40222.5 | -3,889E-07 | 908.6 | 9.319E-15 | 9.866E-15 | 1.072E-14 |

Table.4 (cont'd)

| DATE | TDOT | YBAR | RHO | RHOO | RHOSTD |
|---|---|---|---|---|---|
| 40229.5 | -3.502E-07 | 908.4 | 8.393E-15 | 8.926E-15 | 7.119E-15 |
| 40236.5 | -3.264E-07 | 908.3 | 7.822E-15 | 8.295E-15 | 7.344E-15 |
| 40243.5 | -2.609E-07 | 908.1 | 6.253E-15 | 6.599E-15 | 7.197E-15 |
| 40250.5 | -2.808E-07 | 908.0 | 6.729E-15 | 7.092E-15 | 7.912E-15 |
| 40257.5 | -4.167E-07 | 907.9 | 9.986E-15 | 1.052E-14 | 1.129E-14 |
| 40264.5 | -3.760E-07 | 907.7 | 9.012E-15 | 9.469E-15 | 1.100E-14 |
| 40271.5 | -3.383E-07 | 907.5 | 8.108E-15 | 8.526E-15 | 8.994E-15 |
| 40278.5 | -5.506E-07 | 907.3 | 1.320E-14 | 1.396E-14 | 8.793E-15 |
| 40285.5 | -3.720E-07 | 907.1 | 8.917E-15 | 9.358E-15 | 9.351E-15 |
| 40292.5 | -3.770E-07 | 906.9 | 9.036E-15 | 9.455E-15 | 1.053E-14 |
| 40299.5 | -7.877E-07 | 906.6 | 1.888E-14 | 1.988E-14 | 1.229E-14 |
| 40306.5 | -9.851E-07 | 906.2 | 2.362E-14 | 2.479E-14 | 1.483E-14 |
| 40313.5 | -7.073E-07 | 905.8 | 1.696E-14 | 1.774E-14 | 1.073E-14 |
| 40320.5 | -5.476E-07 | 905.5 | 1.313E-14 | 1.367E-14 | 1.041E-14 |
| 40327.5 | -6.448E-07 | 905.2 | 1.546E-14 | 1.609E-14 | 1.087E-14 |
| 40334.5 | -4.514E-07 | 904.9 | 1.082E-14 | 1.122E-14 | 9.486E-15 |
| 40341.5 | -3.671E-07 | 904.7 | 8.801E-15 | 9.092E-15 | 9.096E-15 |
| 40348.5 | -2.867E-07 | 904.6 | 6.875E-15 | 7.097E-15 | 6.865E-15 |
| 40355.5 | -5.278E-07 | 904.4 | 1.266E-14 | 1.306E-14 | 1.175E-14 |
| 40362.5 | -3.839E-07 | 904.2 | 9.206E-15 | 9.487E-15 | 8.223E-15 |
| 40370.0 | -3.177E-07 | 904.0 | 7.619E-15 | 7.822E-15 | 8.853E-15 |
| 40377.0 | -3.171E-07 | 903.9 | 7.605E-15 | 7.809E-15 | 7.761E-15 |
| 40383.5 | -5.883E-07 | 903.6 | 1.411E-14 | 1.453E-14 | 7.158E-15 |
| 40390.5 | -4.395E-07 | 903.4 | 1.054E-14 | 1.081E-14 | 8.633E-15 |
| 40397.5 | -2.331E-07 | 903.2 | 5.591E-15 | 5.711E-15 | 6.646E-15 |
| 40404.5 | -2.609E-07 | 903.1 | 6.257E-15 | 6.394E-15 | 6.378E-15 |
| 40411.5 | -3.373E-07 | 903.0 | 8.089E-15 | 8.267E-15 | 6.980E-15 |
| 40418.5 | -2.391E-07 | 902.8 | 5.734E-15 | 5.843E-15 | 6.603E-15 |
| 40425.5 | -1.587E-07 | 902.8 | 3.807E-15 | 3.872E-15 | 5.231E-15 |
| 40432.5 | -1.974E-07 | 902.7 | 4.735E-15 | 4.820E-15 | 5.254E-15 |

Table.4 (cont'd)

| DATE | TDOT | YBAR | RHO | RHOO | RHOSTD |
|---|---|---|---|---|---|
| 40439.5 | -3.492E-07 | 902.5 | 8.376E-15 | 8.530E-15 | 7.473E-15 |
| 40446.5 | -2.440E-07 | 902.4 | 5.853E-15 | 5.940E-15 | 8.149E-15 |
| 40453.5 | -1.617E-07 | 902.3 | 3.879E-15 | 3.930E-15 | 6.350E-15 |
| 40460.5 | -2.728E-07 | 902.2 | 6.544E-15 | 6.640E-15 | 7.326E-15 |
| 40467.5 | -3.224E-07 | 902.1 | 7.734E-15 | 7.839E-15 | 8.838E-15 |
| 40474.5 | -2.619E-07 | 901.9 | 6.282E-15 | 6.355E-15 | 9.273E-15 |
| 40481.5 | -3.056E-07 | 901.8 | 7.329E-15 | 7.411E-15 | 9.799E-15 |
| 40488.5 | -4.077E-07 | 901.6 | 9.781E-15 | 9.885E-15 | 1.121E-14 |
| 40495.5 | -4.931E-07 | 901.4 | 1.183E-14 | 1.193E-14 | 1.517E-14 |
| 40502.5 | -3.214E-07 | 901.2 | 7.711E-15 | 7.771E-15 | 9.597E-15 |
| 40509.5 | -2.927E-07 | 901.1 | 7.021E-15 | 7.066E-15 | 9.855E-15 |
| 40516.5 | -3.958E-07 | 900.9 | 9.496E-15 | 9.557E-15 | 8.806E-15 |
| 40523.5 | -5.327E-07 | 900.7 | 1.278E-14 | 1.285E-14 | 9.945E-15 |
| 40530.5 | -3.958E-07 | 900.5 | 9.497E-15 | 9.525E-15 | 1.108E-14 |
| 40537.5 | -4.077E-07 | 900.3 | 9.782E-15 | 9.799E-15 | 1.200E-14 |
| 40544.5 | -4.792E-07 | 900.1 | 1.150E-14 | 1.150E-14 | 9.458E-15 |
| 40551.5 | -6.716E-07 | 899.8 | 1.611E-14 | 1.609E-14 | 1.052E-14 |
| 40558.5 | -5.000E-07 | 899.5 | 1.200E-14 | 1.196E-14 | 1.224E-14 |
| 40565.5 | -3.323E-07 | 899.3 | 7.975E-15 | 7.938E-15 | 9.332E-15 |
| 40573.0 | -3.342E-07 | 899.1 | 8.019E-15 | 7.972E-15 | 7.962E-15 |
| 40580.0 | -4.375E-07 | 899.0 | 1.050E-14 | 1.042E-14 | 9.635E-15 |
| 40586.5 | -3.532E-07 | 898.8 | 8.475E-15 | 8.402E-15 | 7.859E-15 |
| 40593.5 | -2.688E-07 | 898.6 | 6.452E-15 | 6.394E-15 | 7.550E-15 |
| 40600.5 | -4.504E-07 | 898.5 | 1.081E-14 | 1.069E-14 | 8.728E-15 |
| 40607.5 | -5.754E-07 | 898.2 | 1.381E-14 | 1.363E-14 | 1.097E-14 |
| 40614.5 | -3.423E-07 | 898.0 | 8.214E-15 | 8.097E-15 | 7.250E-15 |
| 40622.0 | -3.108E-07 | 897.8 | 7.458E-15 | 7.351E-15 | 8.136E-15 |
| 40629.0 | -3.889E-07 | 897.7 | 9.334E-15 | 9.168E-15 | 6.319E-15 |
| 40635.5 | -5.089E-07 | 897.5 | 1.221E-14 | 1.197E-14 | 6.753E-15 |
| 40642.5 | -4.970E-07 | 897.2 | 1.193E-14 | 1.167E-14 | 7.138E-15 |

Table.4 (cont'd)

| DATE | TDOT | YBAR | RHO | RHOO | RHOSTD |
|---|---|---|---|---|---|
| 40649.5 | -6.012E-07 | 897.0 | 1.443E-14 | 1.409E-14 | 9.061E-15 |
| 40656.5 | -7.143E-07 | 896.7 | 1.715E-14 | 1.071E-14 | 1.153E-14 |
| 40663.5 | -5.298E-07 | 896.4 | 1.272E-14 | 1.239E-14 | 1.110E-14 |
| 40670.5 | -5.685E-07 | 896.1 | 1.365E-14 | 1.325E-14 | 9.887E-15 |
| 40677.5 | -6.587E-07 | 895.8 | 1.581E-14 | 1.532E-14 | 1.162E-14 |
| 40684.5 | -6.657E-07 | 895.5 | 1.598E-14 | 1.541E-14 | 8.071E-15 |
| 40691.5 | -5.327E-07 | 895.2 | 1.279E-14 | 1.232E-14 | 7.944E-15 |
| 40698.5 | -5.486E-07 | 895.0 | 1.317E-14 | 1.272E-14 | 1.289E-14 |
| 40705.5 | -4.454E-07 | 894.7 | 1.070E-14 | 1.030E-14 | 9.777E-15 |
| 40712.5 | -5.744E-07 | 894.5 | 1.379E-14 | 1.324E-14 | 1.117E-14 |
| 40719.5 | -5.794E-07 | 894.2 | 1.391E-14 | 1.330E-14 | 9.248E-15 |
| 40726.5 | -6.300E-07 | 893.9 | 1.513E-14 | 1.442E-14 | 8.995E-15 |
| 40733.5 | -5.665E-07 | 893.6 | 1.360E-14 | 1.297E-14 | 1.039E-14 |
| 40740.5 | -4.514E-07 | 893.4 | 1.084E-14 | 1.034E-14 | 9.948E-15 |
| 40747.5 | -3.423E-07 | 893.2 | 8.220E-15 | 7.841E-15 | 8.048E-15 |
| 40754.5 | -5.437E-07 | 893.0 | 1.306E-14 | 1.235E-14 | 7.862E-15 |
| 40761.5 | -3.849E-07 | 892.8 | 9.245E-15 | 8.773E-15 | 7.878E-15 |
| 40768.0 | -4.757E-07 | 892.5 | 1.143E-14 | 1.079E-14 | 7.976E-15 |
| 40774.5 | -4.742E-07 | 892.3 | 1.139E-14 | 1.073E-14 | 7.663E-15 |
| 40781.5 | -2.669E-07 | 892.2 | 6.410E-15 | 6.082E-15 | 6.896E-15 |
| 40789.0 | -2.969E-07 | 892.0 | 7.131E-15 | 6.747E-15 | 6.916E-15 |
| 40796.5 | -3.859E-07 | 891.9 | 9.270E-15 | 8.731E-15 | 7.424E-15 |
| 40803.5 | -1.796E-07 | 891.7 | 4.313E-15 | 4.083E-15 | 4.788E-15 |
| 40810.5 | -2.054E-07 | 891.7 | 4.933E-15 | 4.665E-15 | 5.356E-15 |
| 40817.5 | -3.244E-07 | 891.5 | 7.792E-15 | 7.348E-15 | 7.633E-15 |
| 40824.5 | -2.956E-07 | 891.4 | 7.102E-15 | 6.708E-15 | 7.974E-15 |
| 40832.0 | -3.958E-07 | 891.2 | 9.509E-15 | 8.949E-15 | 9.446E-15 |
| 40839.0 | -4.352E-07 | 891.0 | 1.045E-14 | 9.830E-15 | 1.060E-14 |
| 40849.0 | -3.839E-07 | 890.7 | 9.223E-15 | 8.689E-15 | 1.107E-14 |
| 40859.5 | -4.206E-07 | 890.4 | 1.011E-14 | 9.486E-15 | 1.126E-14 |

Table.4 (concl'd)

| DATE | TDOT | YBAR | RHO | RHOO | RHOSYD |
|---|---|---|---|---|---|
| 40867.0 | -3.307E-07 | 890.3 | 7.946E-15 | 7.452E-15 | 8.962E-15 |
| 40874.5 | -5.238E-07 | 890.0 | 1.258E-14 | 1.179E-14 | 1.457E-14 |
| 40881.0 | -6.458E-07 | 889.8 | 1.552E-14 | 1.449E-14 | 1.689E-14 |
| 40887.5 | -7.589E-07 | 889.5 | 1.824E-14 | 1.685E-14 | 1.368E-14 |
| 40894.5 | -8.244E-07 | 889.1 | 1.981E-14 | 1.834E-14 | 1.807E-14 |
| 40902.0 | -7.309E-07 | 888.7 | 1.756E-14 | 1.618E-14 | 1.456E-14 |
| 40909.0 | -6.655E-07 | 888.4 | 1.599E-14 | 1.460E-14 | 9.853E-15 |
| 40916.0 | -5.425E-07 | 888.1 | 1.304E-14 | 1.198E-14 | 1.191E-14 |

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Fig.1





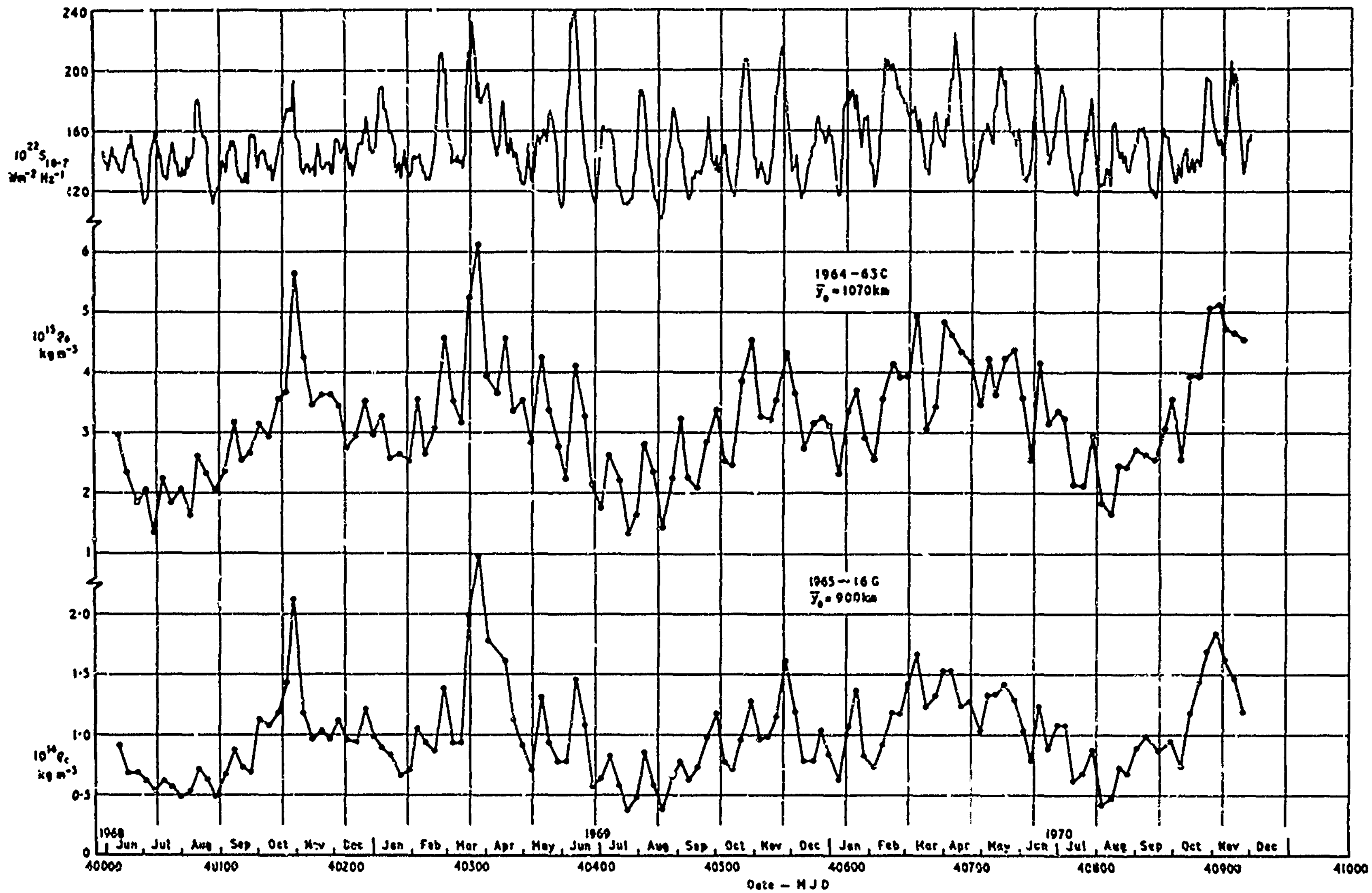


Fig.1 Values of $\rho_0$, the density adjusted to the fixed height $\bar{y}_0$, obtained from NRL data for 1964-63C and 1965-16G

Fig.2

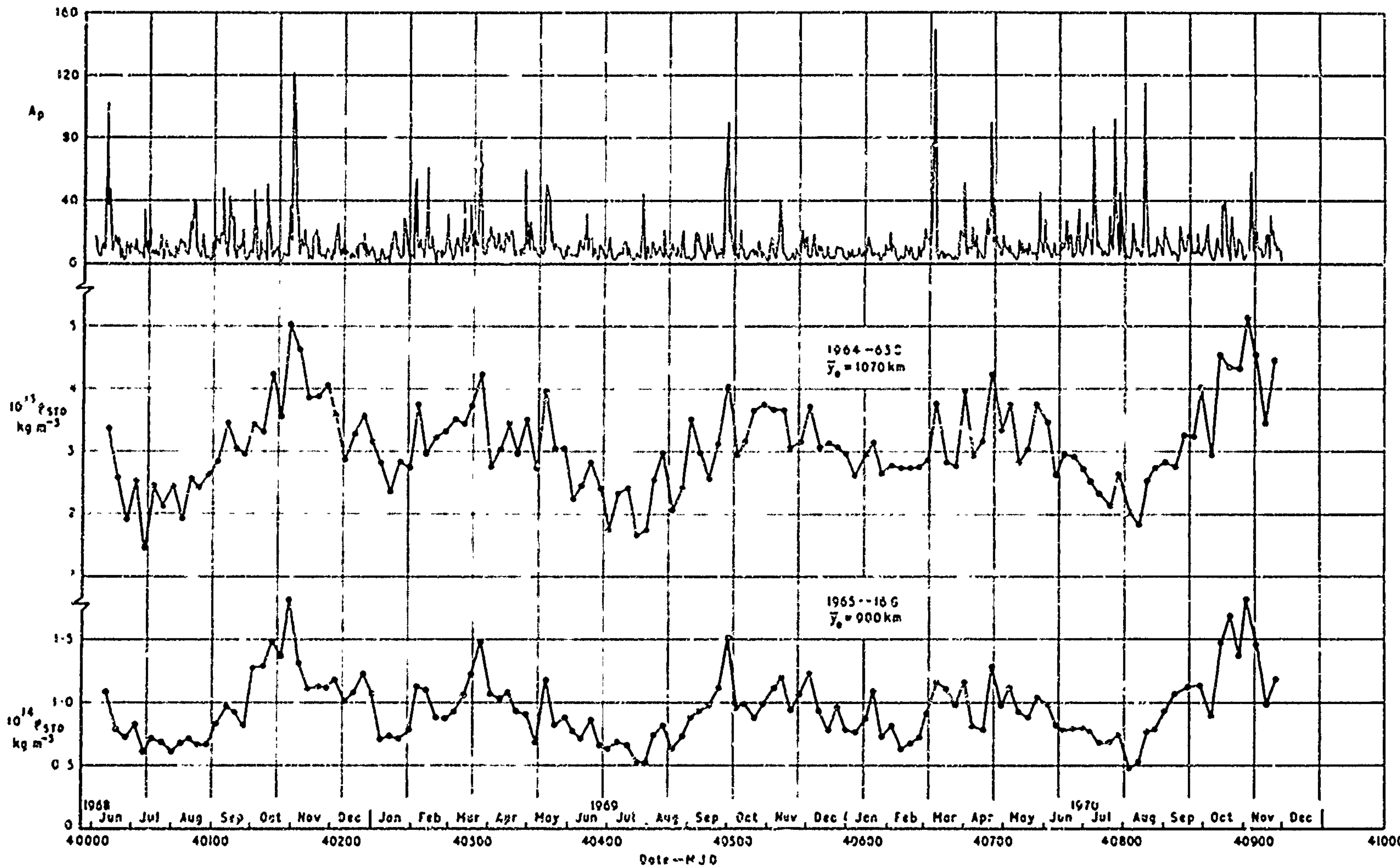


Fig.2 Values of $\rho_{STD}$, the density adjusted to a fixed height $\bar{y}_0$ and a fixed flux of $10^{22} S_{STD} = 150$, obtained from NRL data for 1964-63C and 1965-16G

854 803251

TR 71150

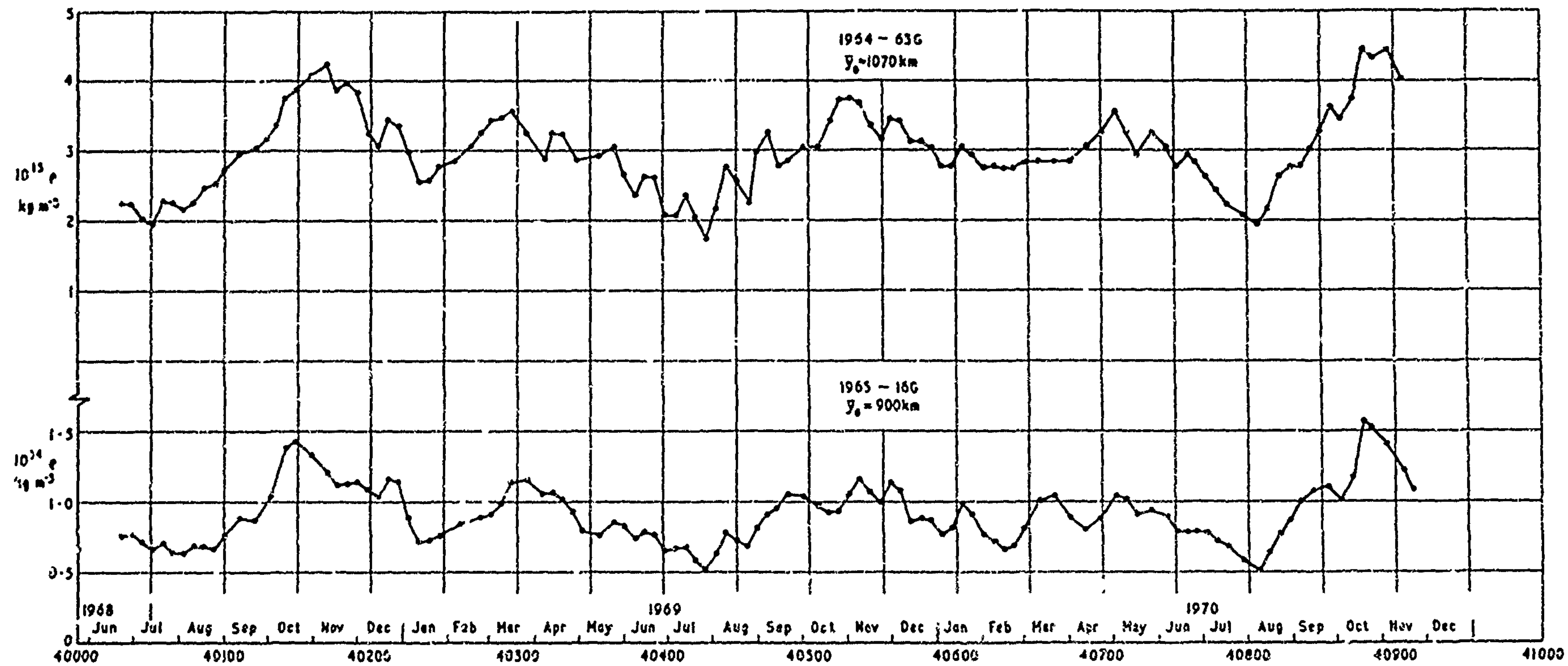


Fig.3 Variation of air density from NRL data after smoothing

Fig.3

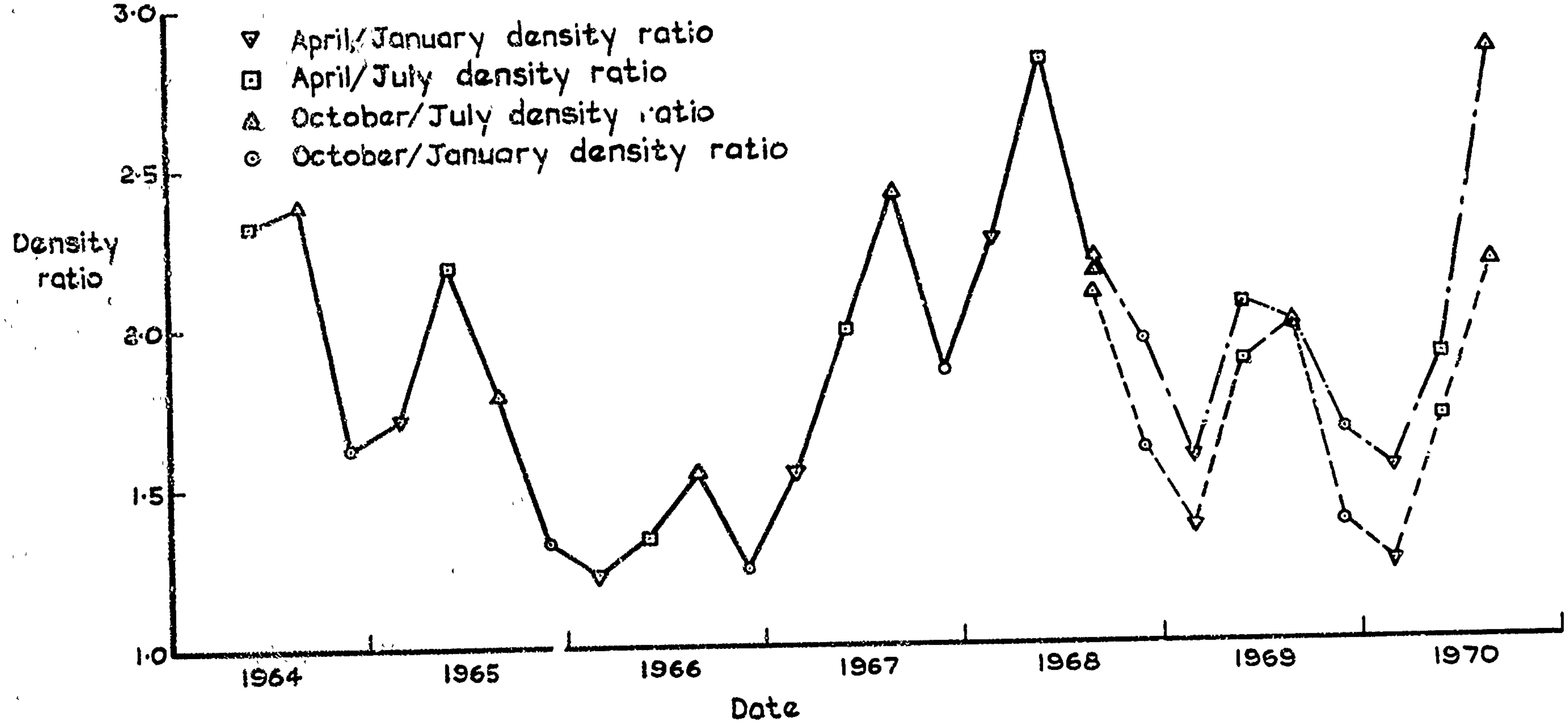


Fig.4 Magnitude of the semi-annual variation in the exosphere

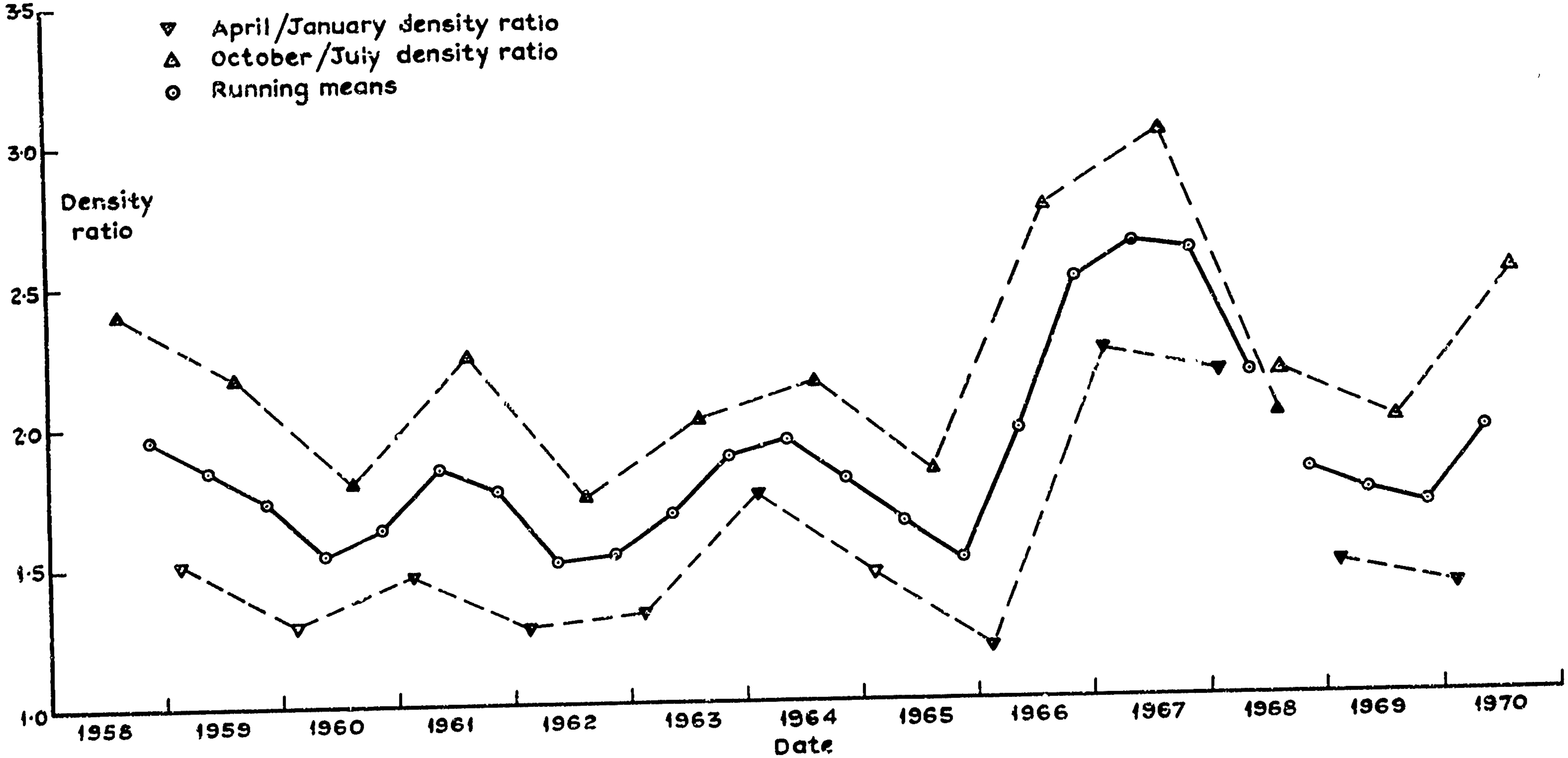


Fig.5 Magnitude of the semi-annual variation in air density at a height of 500 km from 1958 - 1968 and at heights near 1000 km from 1968 - 1970

Fig.6

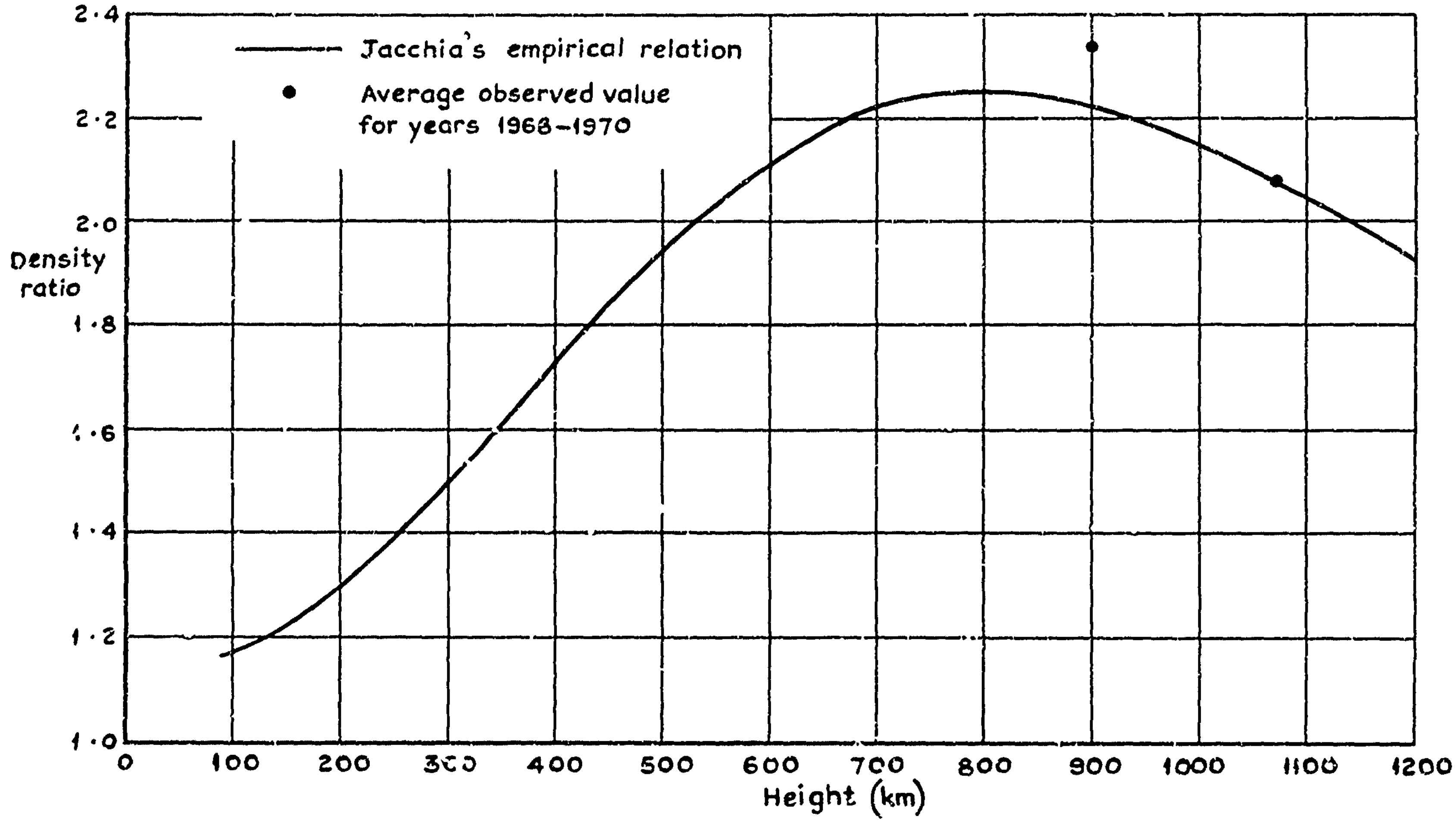


Fig.6 Variation with height of the October / July density ratio